2011 NASA Aerospace Battery Workshop
November 15th – 17th, 2011
Huntsville, Alabama

Development of 120V Batteries for the ORION Multi-Purpose Crew Vehicle

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Space Programs

Mars Missions:

Phoenix Lander

MER Spirit and Opportunity

MSL

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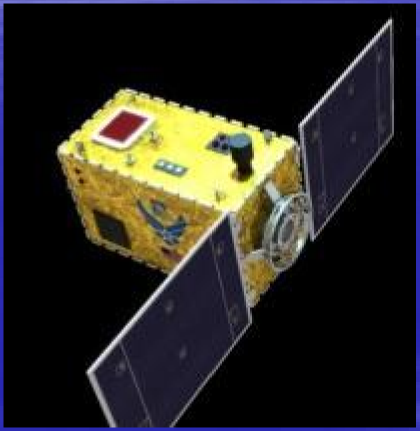
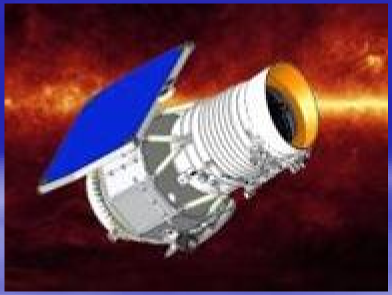
Space Programs

Satellites:

XSS-11



WISE



Orbital Express

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Recently:

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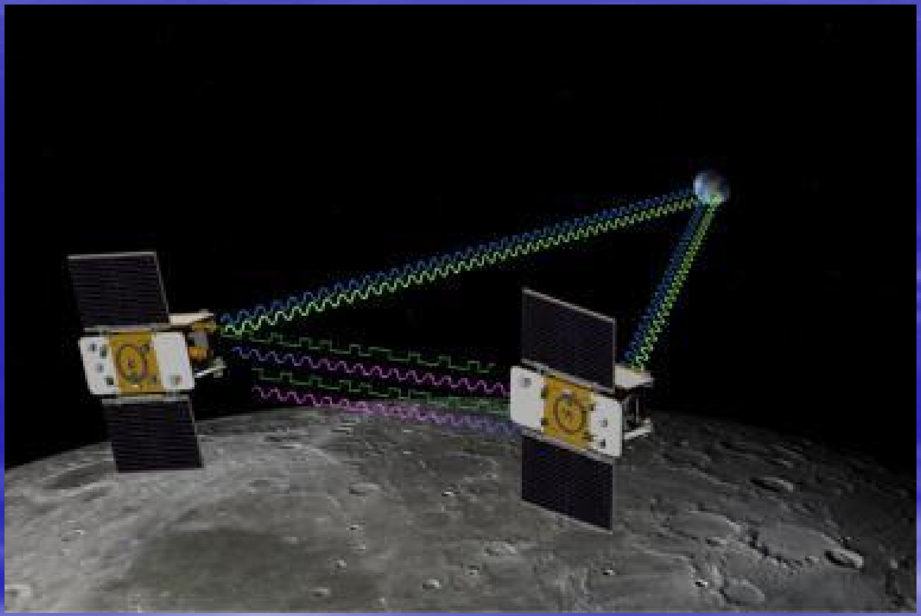
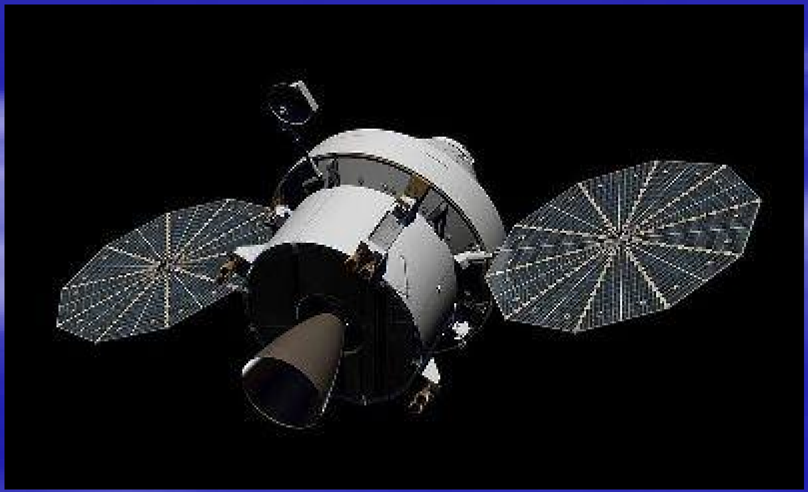


September 10, 2011

NASA / Lockheed

ORION Multi-Purpose Crew Vehicle

- Originally Part of NASA's Constellation Program as the Crew Exploration Vehicle
- Constellation is no longer an active program
- The design was carried forward as the ORION Multi-Purpose Crew Vehicle



: Mission :

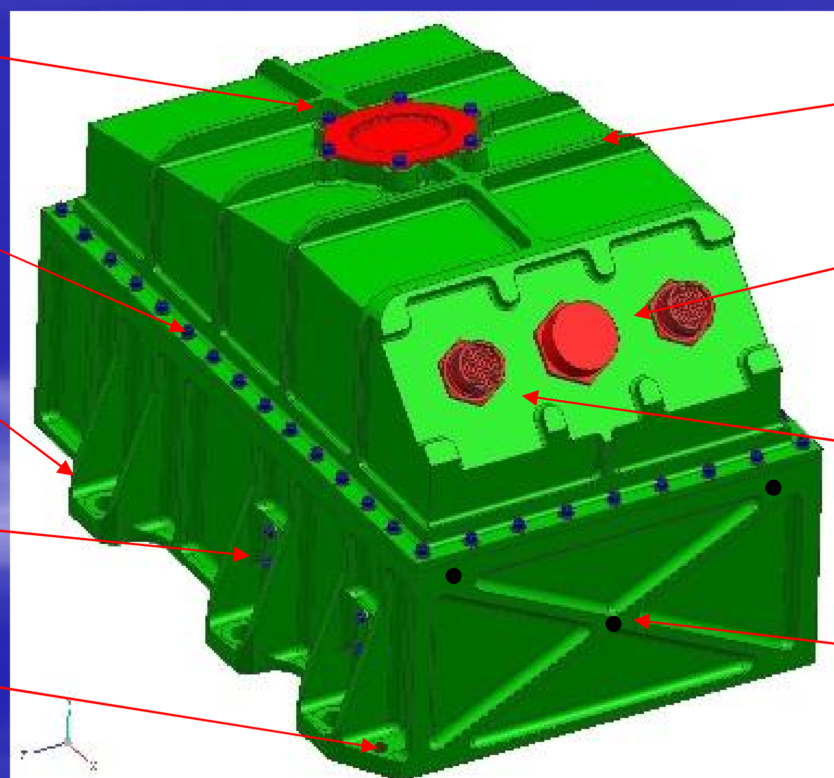
Explore beyond low earth orbit and into deep space.

Yardney Lithion

MPCV Battery

Exterior Features

Specification: 120V Lithium-ion 30Ah Battery



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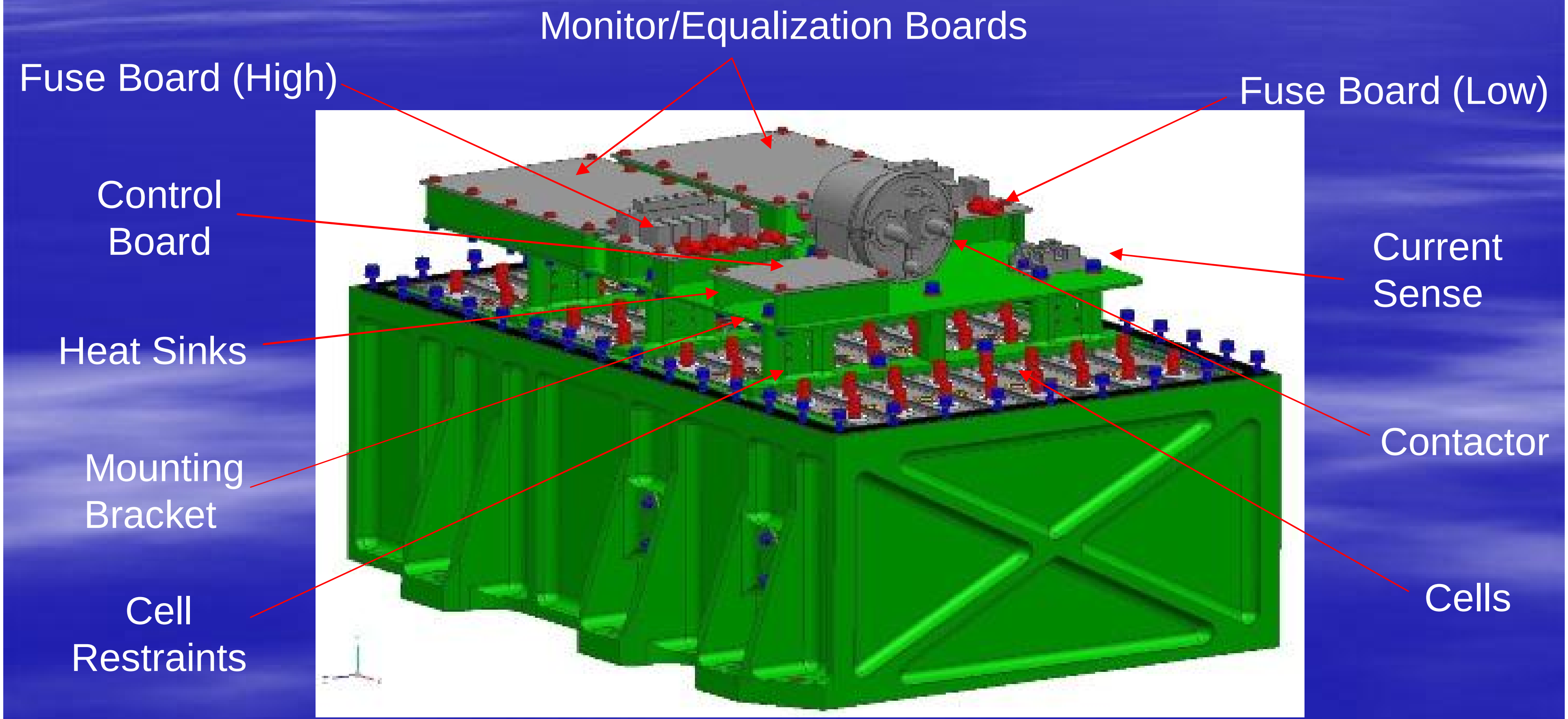
Interior Features

Specification: 120V Lithium-ion 30Ah Battery



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Main Challenge

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In the ongoing design of the Crew Module Battery for the MPCV, Yardney has been encountering numerous hurdles.

- Development of new chemistry
- Dual Independent coil contactor

The one that deserves honorable mention is:

- Meeting the strict envelope requirements laid out in the vehicle for the battery.

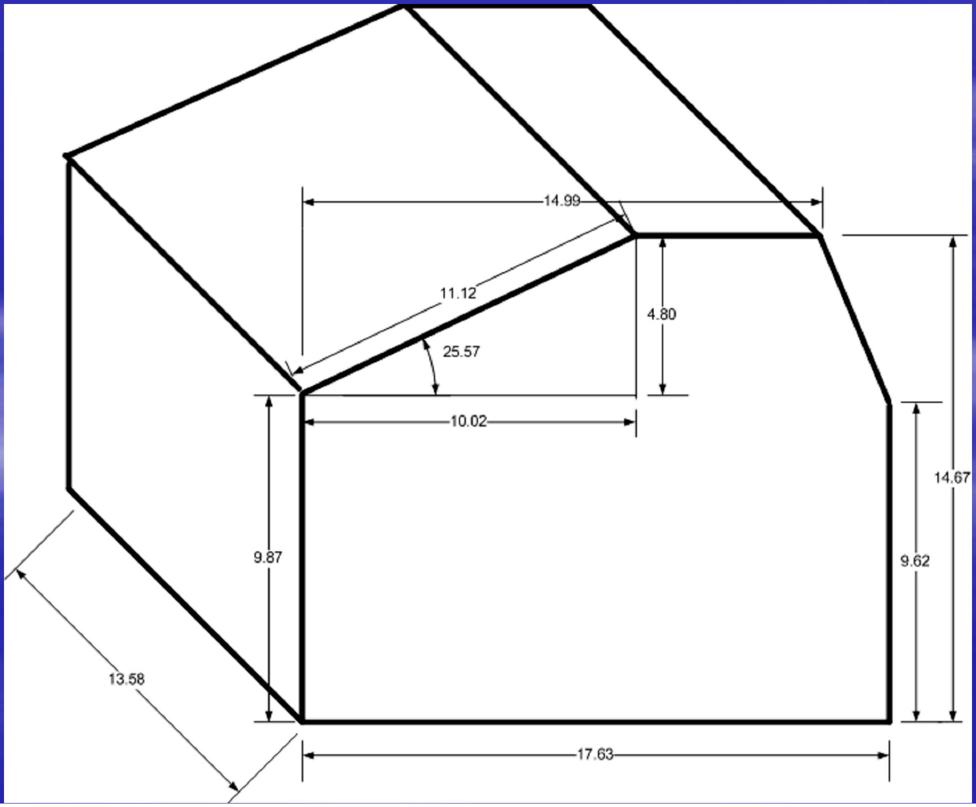
The purpose of this presentation is to walk you through the engineering challenges faced, and how they were solved, in meeting envelope requirements for the MPCV Battery.

MPCV Battery

Envelope

Minimal envelope available to the design of the battery

- Nominal 120V battery requires 32 prismatic cells
- Complications such as very high vibration and shock loads also had to be considered
- Lets not forget to mention that the battery needs to function submerged in seawater



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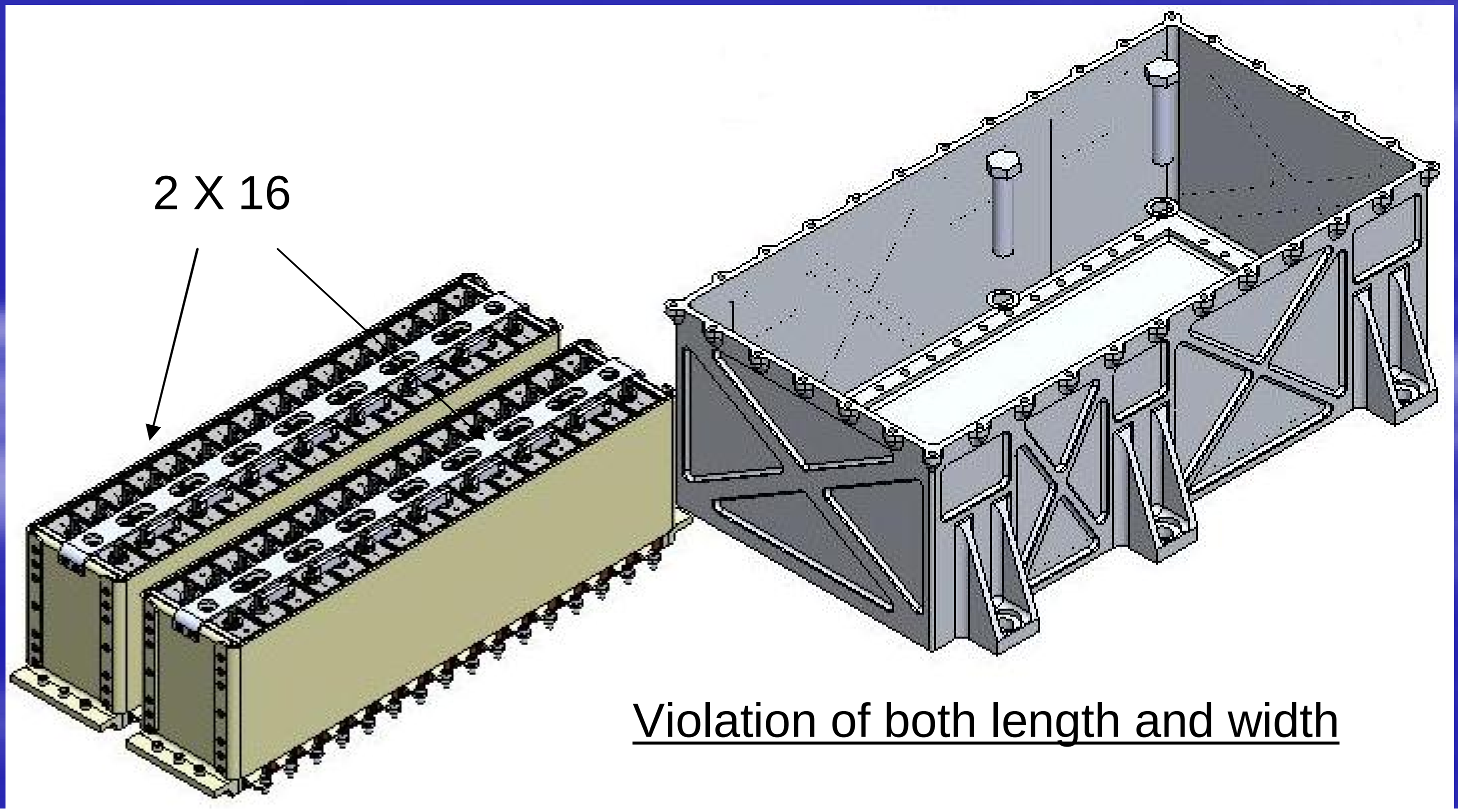
Traditional Cell Stack

Traditional Approach – Cell stack with bolt-on jacket installed inside housing

- Stack is measured, shimmed, and compressed.
- Jacket is installed (Jacket allows for breathing of cells)
- Subassembly is bolted into bottom of housing



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Non-Traditional Cell Stacks

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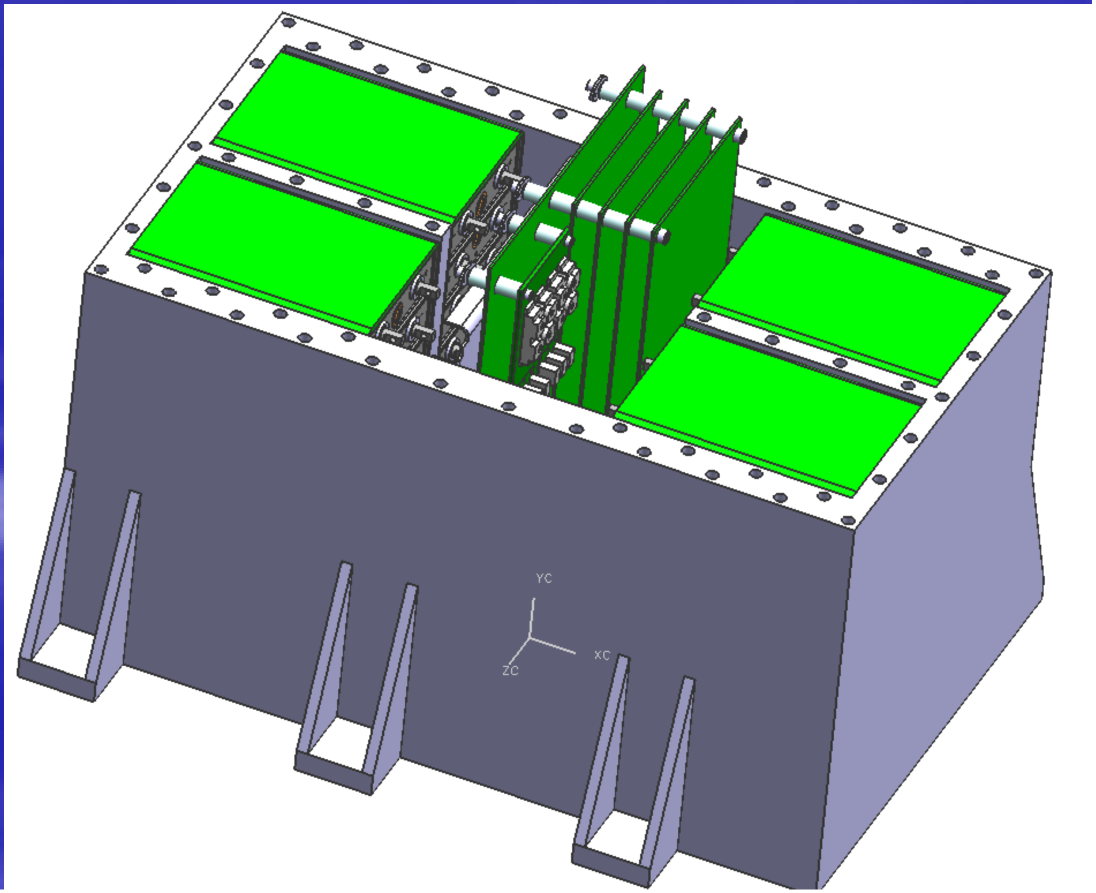
One iteration featured the cell stacks horizontally stacked on one another with the electronics package in the middle.

CONCERNS:

• High stresses during vibration made it difficult to hold the stacks in place.
• Nearly impossible to dissipate the heat from the electronics boards.
• Safety concern, nicknamed the 'Old West' design, cell burst discs pointing at one another.



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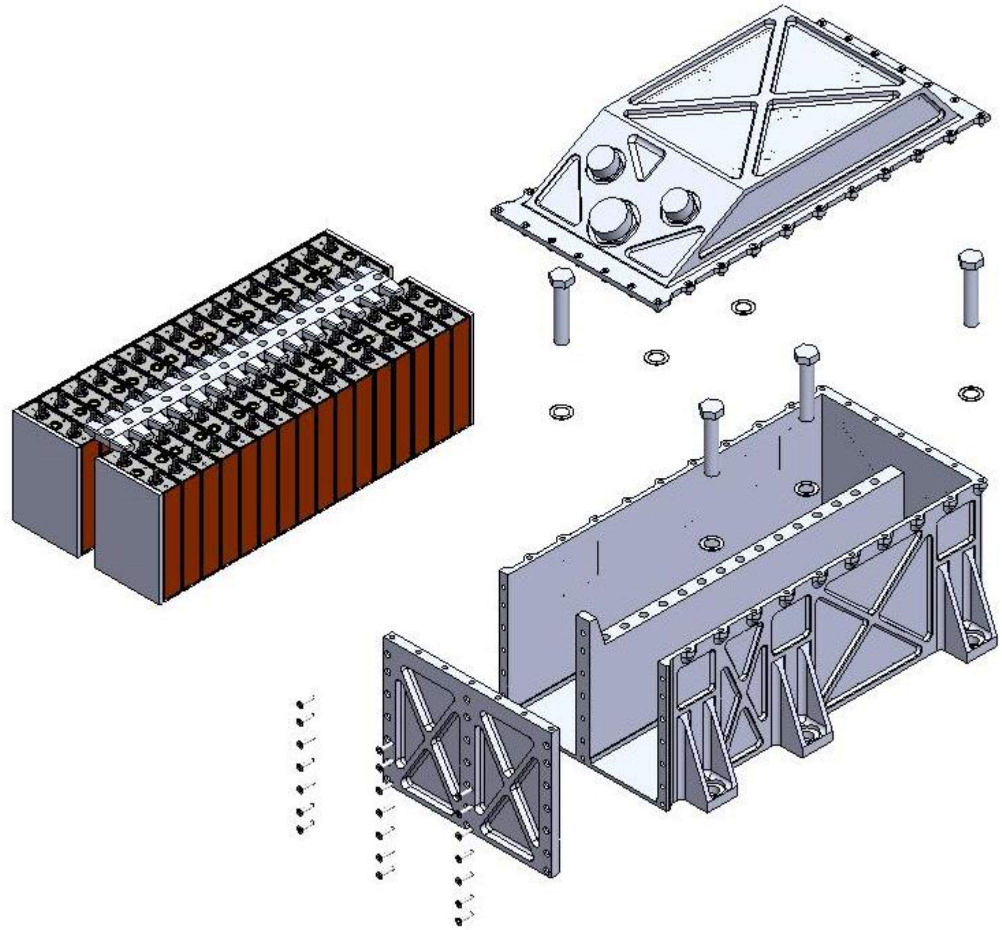
Non-Traditional Cell Stack

Another iteration featured the cell stacks vertically in 2 rows of 16. Much like the traditional style looked at only without the jacket..

CONCERNS:

- High stresses on the bolted end wall during cell cycling/expansion.
- It was difficult to imagine how to seal the box for under water operations.
- Hold on. That is going to be tricky to mount the electronics.



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Non-Traditional Solution

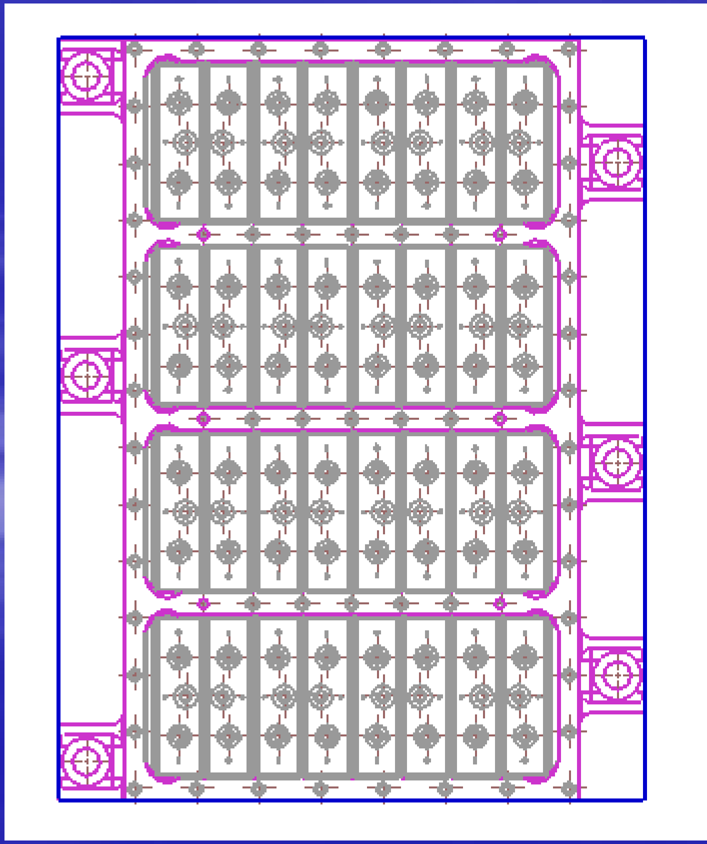
After numerous iterations of cell stacking – Non-Traditional solution finally reached

MPCV, 120Vdc	
Cell Model	NCP25-5
Cell Stacks	4 X 8
Compression Method	Housing, Forced Shims

Envelope Violation = None

Weight (Approx.) = 98.7 LBM

RISKS:
Non-Traditional Assembly Procedure



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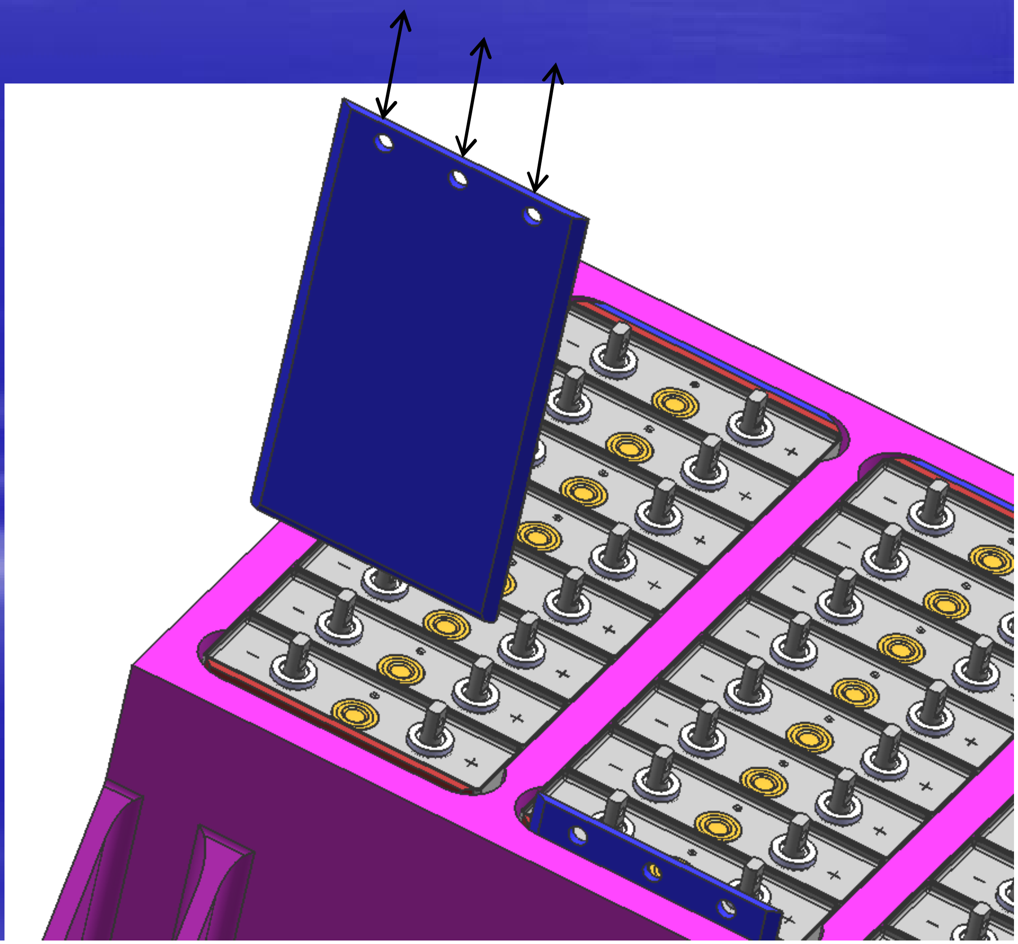
Non-Traditional Assembly

Addressing the risk – Non-Traditional Assembly Procedure

Forced Shim Assembly or ñShim Packò Approach

- Stack is measured and installed with sized shims loose in housing
- Special shim with shallow lead chamfers is forced in via arbor or hydraulic press
- Shim is removed by application of force to protruding end



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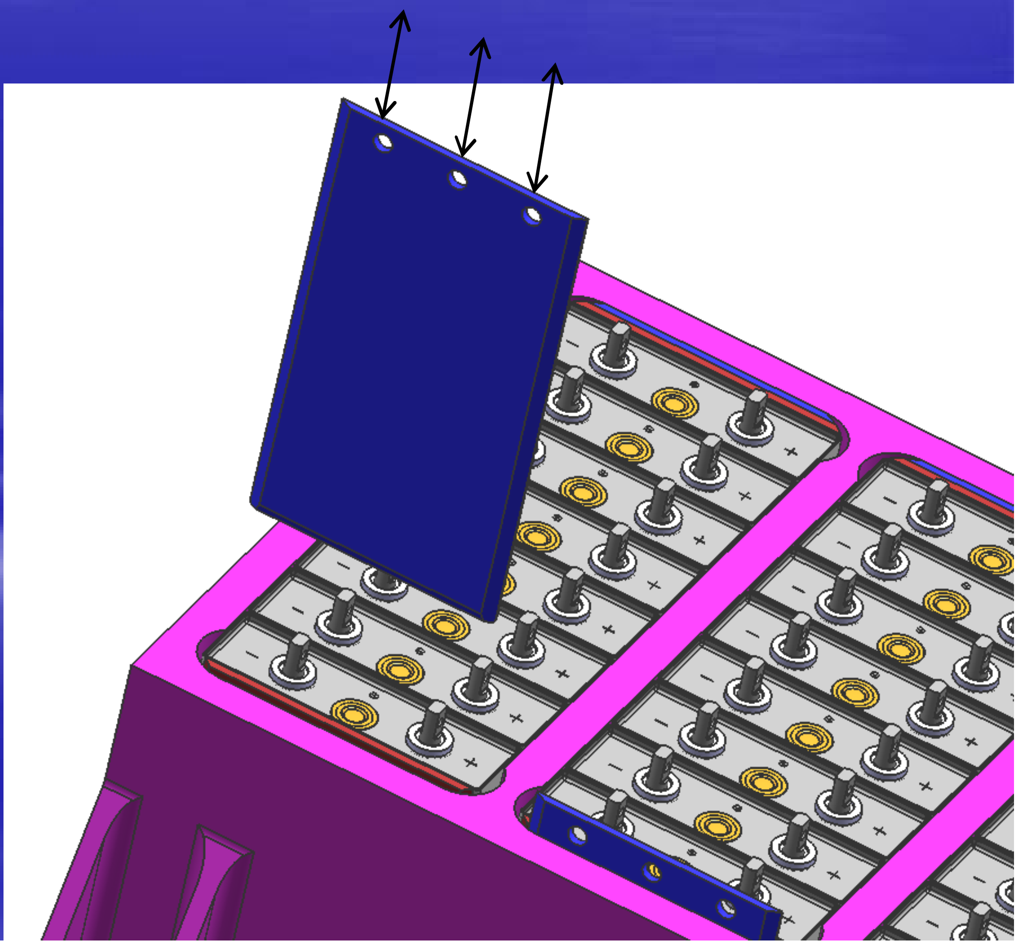
Assessing Forced Shim Design

Testing was performed on the "Forced Shim Pack" approach utilizing a rigid single mock bay.

- 7 NCP25-1 cells were placed in the mock bay along with a load cell.
- The bay was then filled with .016" thick G10 shim
- The chamfered stainless steel shim was then slowly pressed in with an arbor press
- A target force of 1,000 lbf was the goal

- Electrical cycling was then performed on the pack to record load cell variations



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Results Forced Shim Design

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ENGINEERING ISSUES / CONCERNS RAISED

- **Generation of foreign object debris (FOD)**
  During the iterations of CRES shim insertion using the arbor press to attain the target force of 1,000 LBS on the stack, the shim had visible scratch marks throughout the length of the plunge. X

- **Drastic change in forces exerted on case/cell stack during cycling**
  During electrical cycling the original 1,000 lbf on the pack changed with the voltage. At peak voltage of 4.1V/cell the pack averaged 2,000lbf while at a low votage of 3.0V/cell the pack averaged 780 lbf. Box is too stiff. X

- **Impractical rework – Safety concerns**
  Post testing the pack was to be disassembled for inspection. Numerous efforts to remove the "forced shim" failed. An unconventional (and crude) method using a hammer wrench eventually worked. X

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Engineering Solution ï Spring Shim

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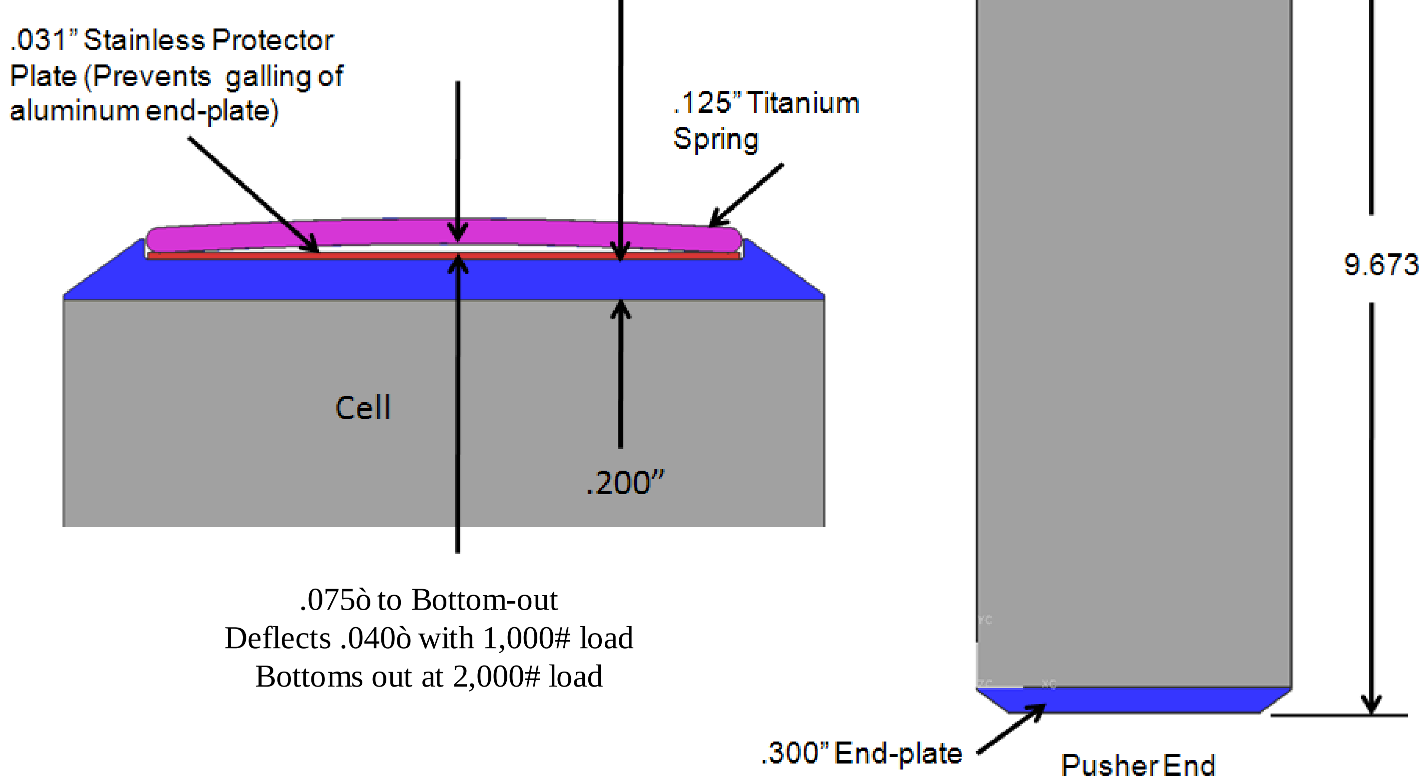
To solve the concerns that were raised by engineering from the test results:

- FOD Generation
- Delta Forces
- No Rework

Single Leaf Spring Design

Single Leaf Spring Design

- Slotted End-plate
- Full width opposite pusher end only
- 1 - .125" Leaf Spring for each stack



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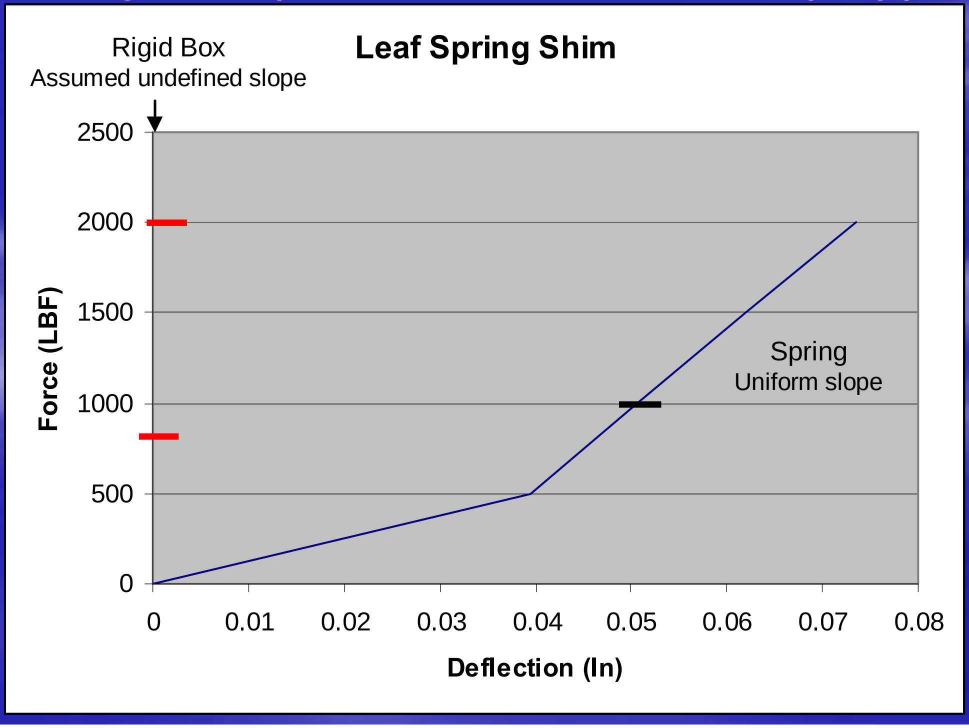
Address Wide Change in Force

Testing of the leaf spring showed promising results:

Preload = 1,000lbf
Rigid Box Tests: Force Tolerances -220lbf to +1,000lbf

Spring will create a tighter force tolerance on the cell stack thus allowing for expansion and contraction (Happier Cells)



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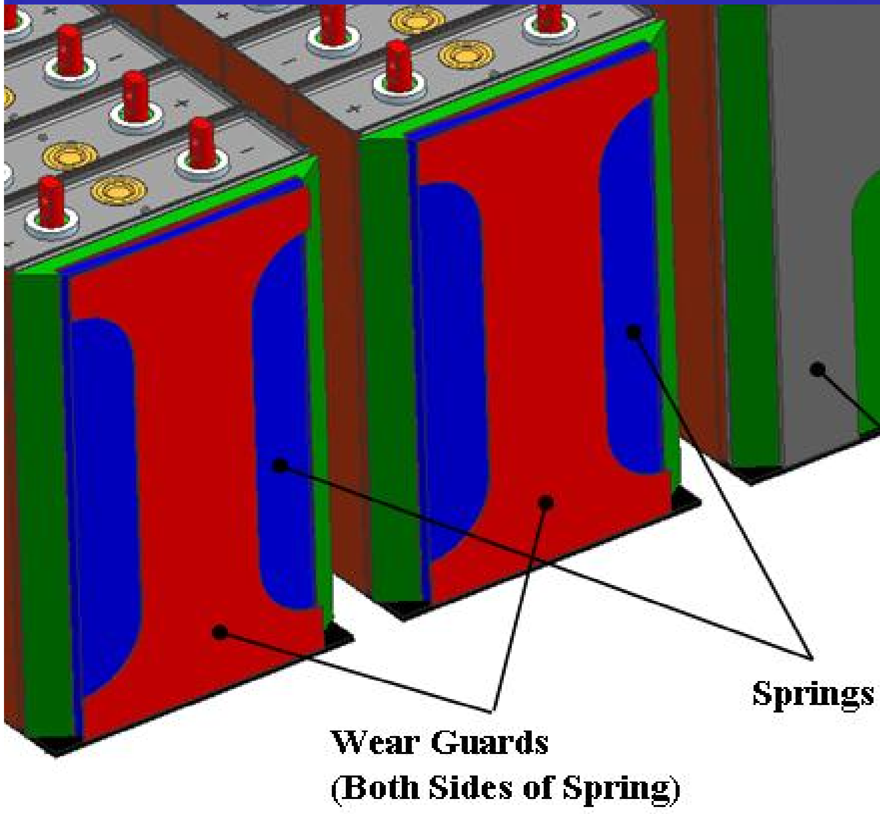
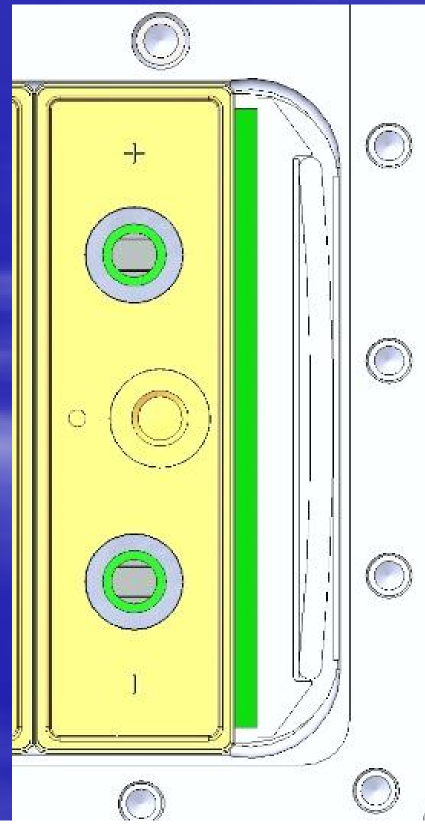
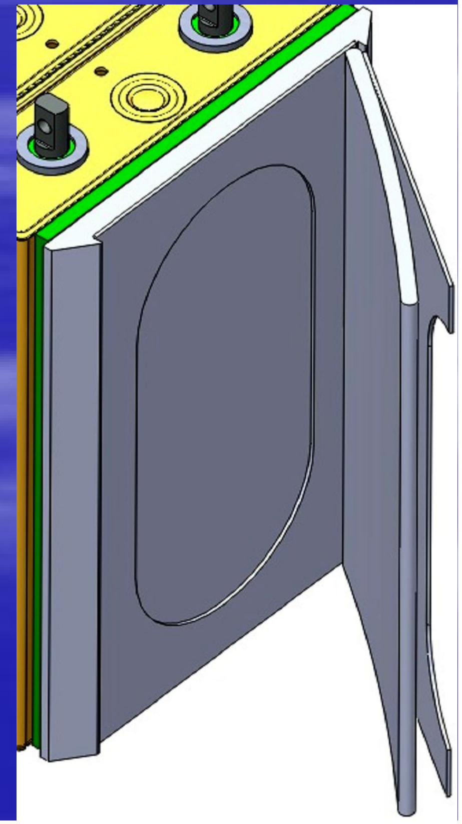
Address FOD

To address the issue of FOD:

Stainless Steel wear guards were placed on each side of the Titanium spring. These plates are to preclude galling on the Aluminum end plate and Housing. Also, the edges of the spring are rounded off to give more of a rolling motion during displacement







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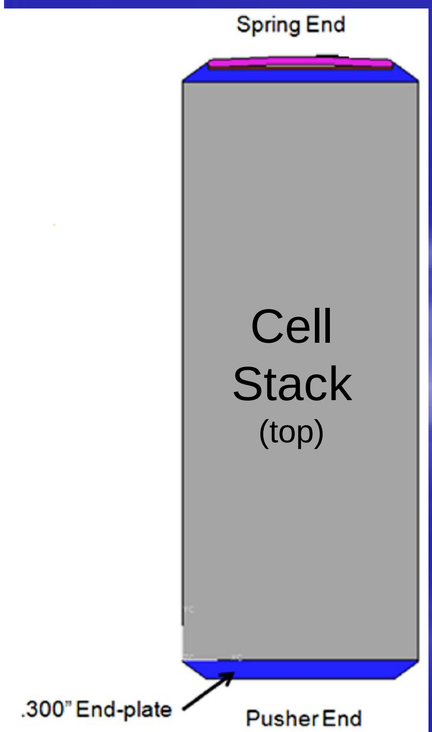
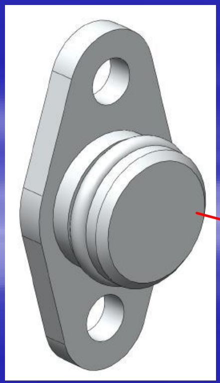
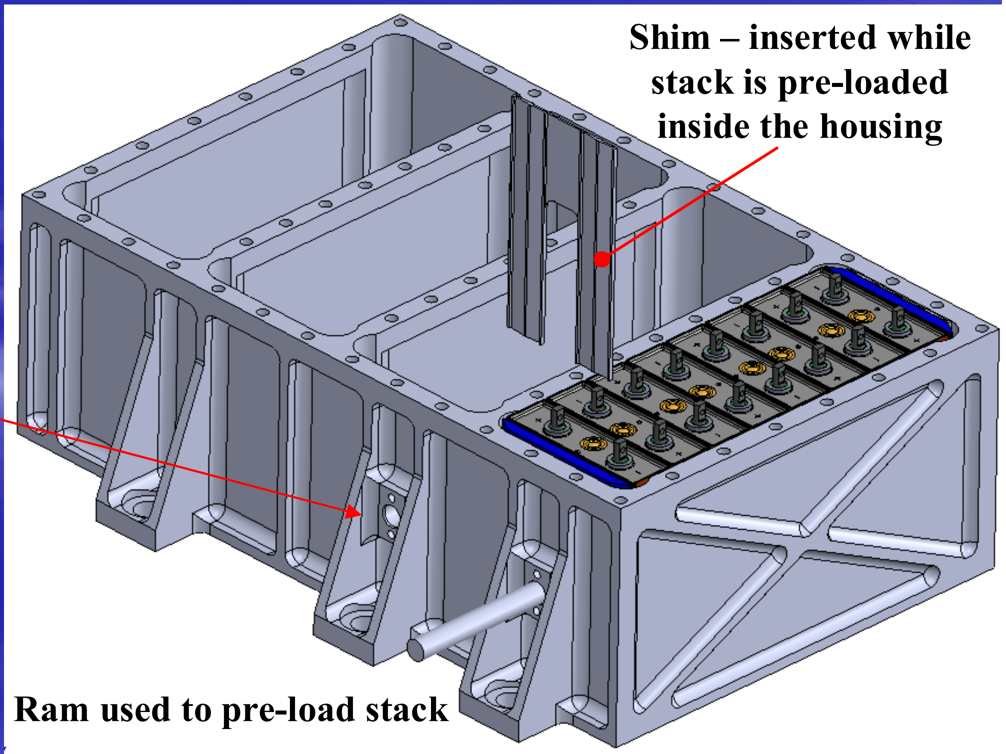
Address Rework

With the cell stack, end plates, and spring loaded into the battery bay a hydraulic ram is used to push on the "pusher plate" through a small opening in the side of the bay to a preload of 1,000lbf . Gauge shims (of varied thickness) are then placed in the bay to ascertain number and size of final shim placements. The stack is then loaded further to allow for installation of final shims, ram is released and hole is plugged.







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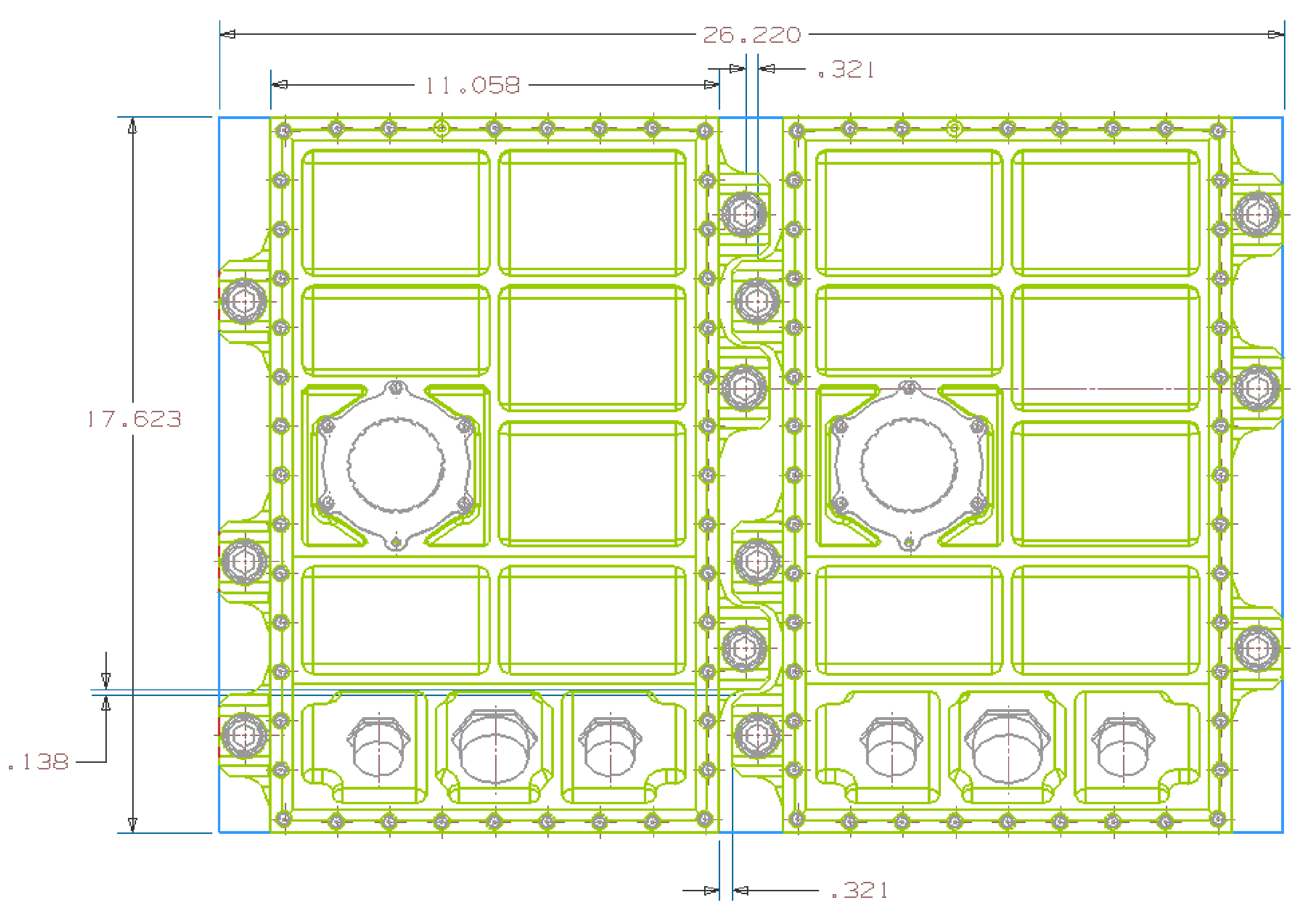
Save More Space

SUGGESTION: Mount the batteries in tandem by designing interlocking feet

Does not sound like much – but 13.2in^2 is a couple acres on a spacecraft



MPCV Battery

Efforts Recognized

Lockheed Martin Space Systems Company

Certificate of Appreciation

is hereby presented to

Yardney Technical Products

In recognition of your outstanding contributions and leadership in meeting Orion Crew Module Battery (CMB) volume constraints, Lockheed Martin is proud to present this Certificate of Appreciation. During preparations for the Orion Preliminary Design Review (PDR), it was realized that the CMB design volume exceeded constraints within the CM aft bay. Yardney provided a prompt and innovative packaging solution to the problem. Your response was critical to a successful PDR and to the continued success of the Orion project.

Cleon Lacefield
Vice President and
Orion Program Manager
Lockheed Martin Space Systems

Robert Thompson
Manager—Supplier Diversity
Lockheed Martin Space Systems

Albert Daniel Hall
Orion Battery CPE
Lockheed Martin Space Systems

ORION

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Yardney Technical Products

Facility Move

Yardney is moving its operations to East Greenwich RI

- Planning and Facilitization ï Summer 2011
- Imara equipment installation ï Fall 2011
- Equipment prove-in (start production in RI) ï Spring 2012
- Existing equipment transfer ï Summer 2012
- Process prove-in ï Fall/Winter 2012
- Full production in RI ï Early 2013

Yardney will continue its development of high quality batteries